A General Framework for SUSY Breaking

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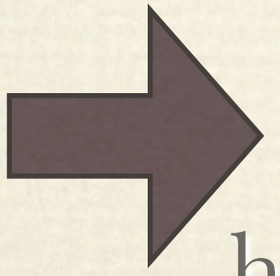
Benchmark models

- Particular SUSY breaking models are used in designing triggers, constraining SUSY parameter space
  - SPS points
  - 6 mSUGRA points, 2 GMSB points, 1 AMSB point
- Theoretical/Experimental prejudices about spectra result

- These prejudices can have important implications for SUSY searches
  - Jets + mET searches for gluinos
  - in mSUGRA $m_{\tilde{g}} : m_{\tilde{B}} = 6 : 1$
  - This ratio never scanned in mSUGRA motivated searches



Kinematically accessible regions which have never been scanned over in searches

Alwall, Le, Lisanti, Wacker

- It's been shown simple 1-parameter extensions blow these theoretical prejudices away
  - Within mSUGRA, small mu FP region occurs for $m_0 \gg m_{1/2}$
    - scalars are decoupled at LHC
  - Within mSUGRA wino content of LSP is never large, and we never get Bino-Wino coannihilation

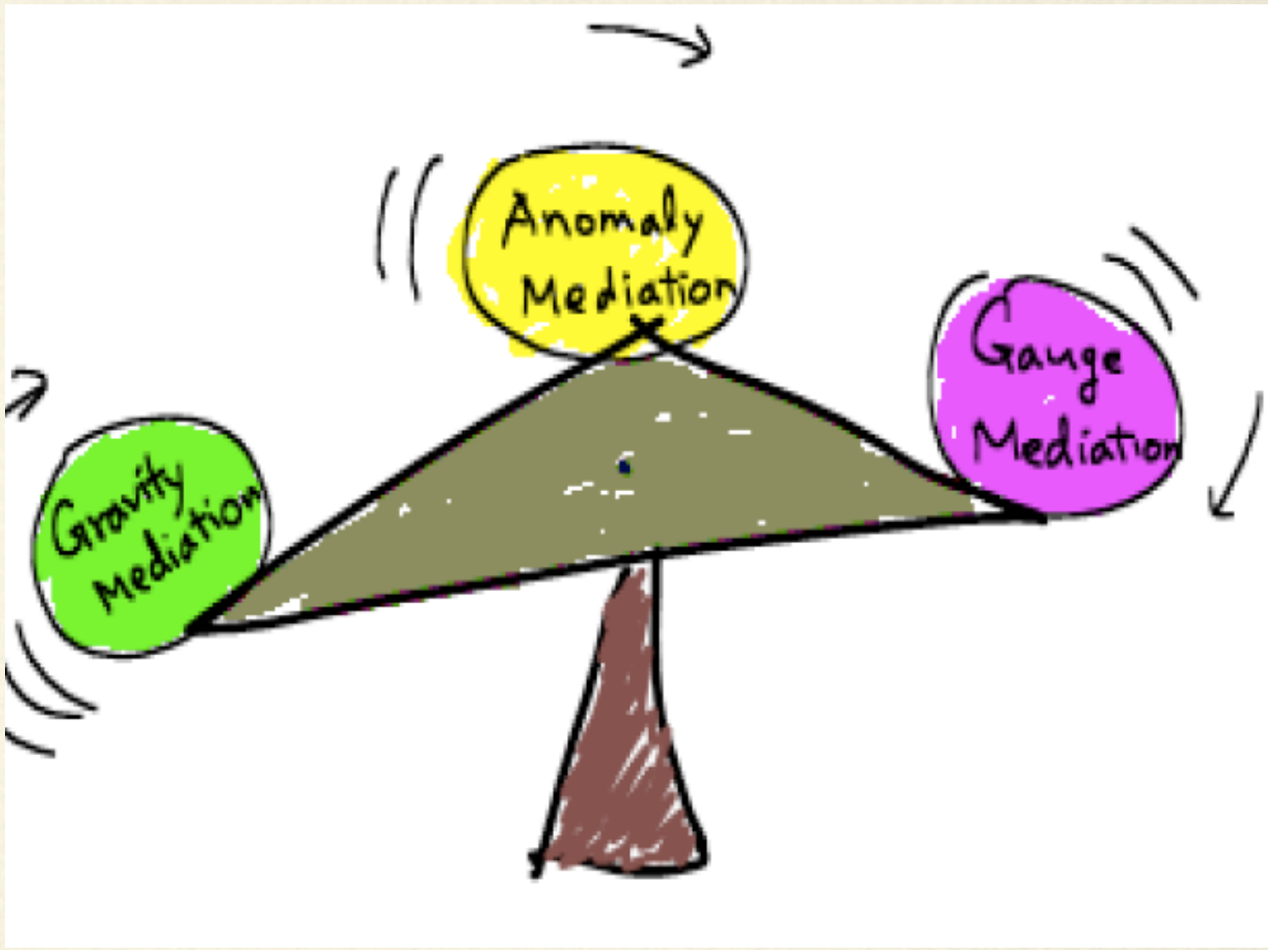
$$M_1(\text{weak}) \simeq M_2(\text{weak}) \Longrightarrow \text{Mixed wino DM (MWDM);}$$
$$M_1(\text{weak}) \simeq -M_2(\text{weak}) \Longrightarrow \text{bino-wino co-annihilation (BWCA);}$$
$$\text{Low } |M_3| \text{ or large } M_2 \Longrightarrow \text{Low } |\mu|, \text{ so mixed higgsino DM (MHDM).}$$

- By adjusting one parameter, all points in $m_0 - m_{1/2}$ plane become relic density allowed!

Baer, Tata et al.

A more general framework?

- Is there a framework?
- Is it well-motivated?
- Does it produce phenomenologically novel MSSM spectra?



- A framework for dialing between any of these types of SUSY breaking schemes

Different mediation mechanisms have different spectra

Gravity Mediation

$$m_{\rm soft} \approx m_{3/2} \approx \frac{F}{M_P}$$

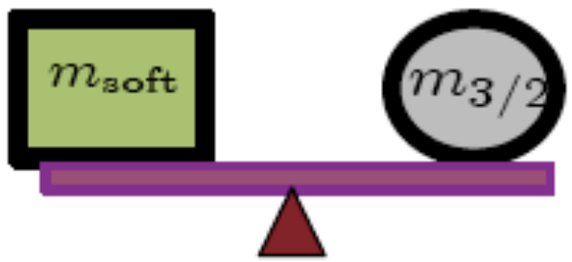
Gauge Mediation

$$m_{\rm soft} \approx \frac{g^2}{16\pi^2}\frac{F}{M_{\rm mess}} \gg m_{3/2} \approx \frac{F}{M_P}$$

Anomaly Mediation

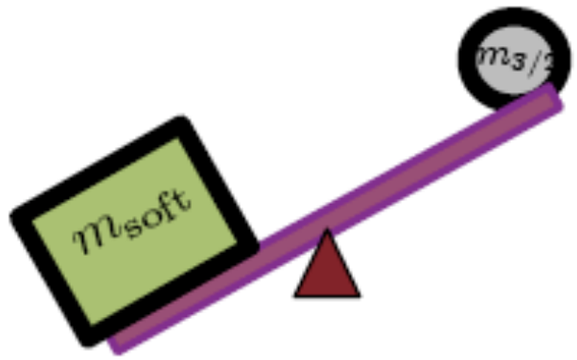
$$m_{\rm soft} \approx \frac{g^2}{16\pi^2} m_{3/2}$$

How to get gravity and anomaly contributions of same size?

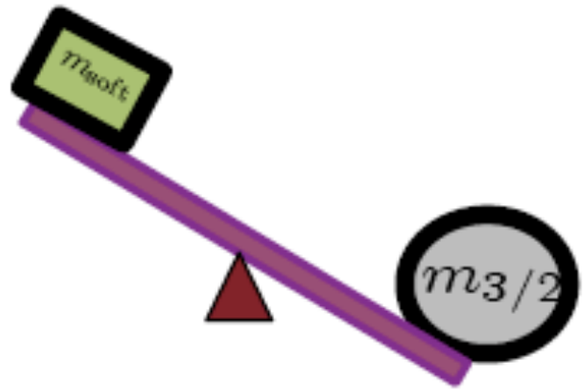


$$M_1 : M_2 : M_3 \simeq 1 : 2 : 6$$

Tree level



One loop level

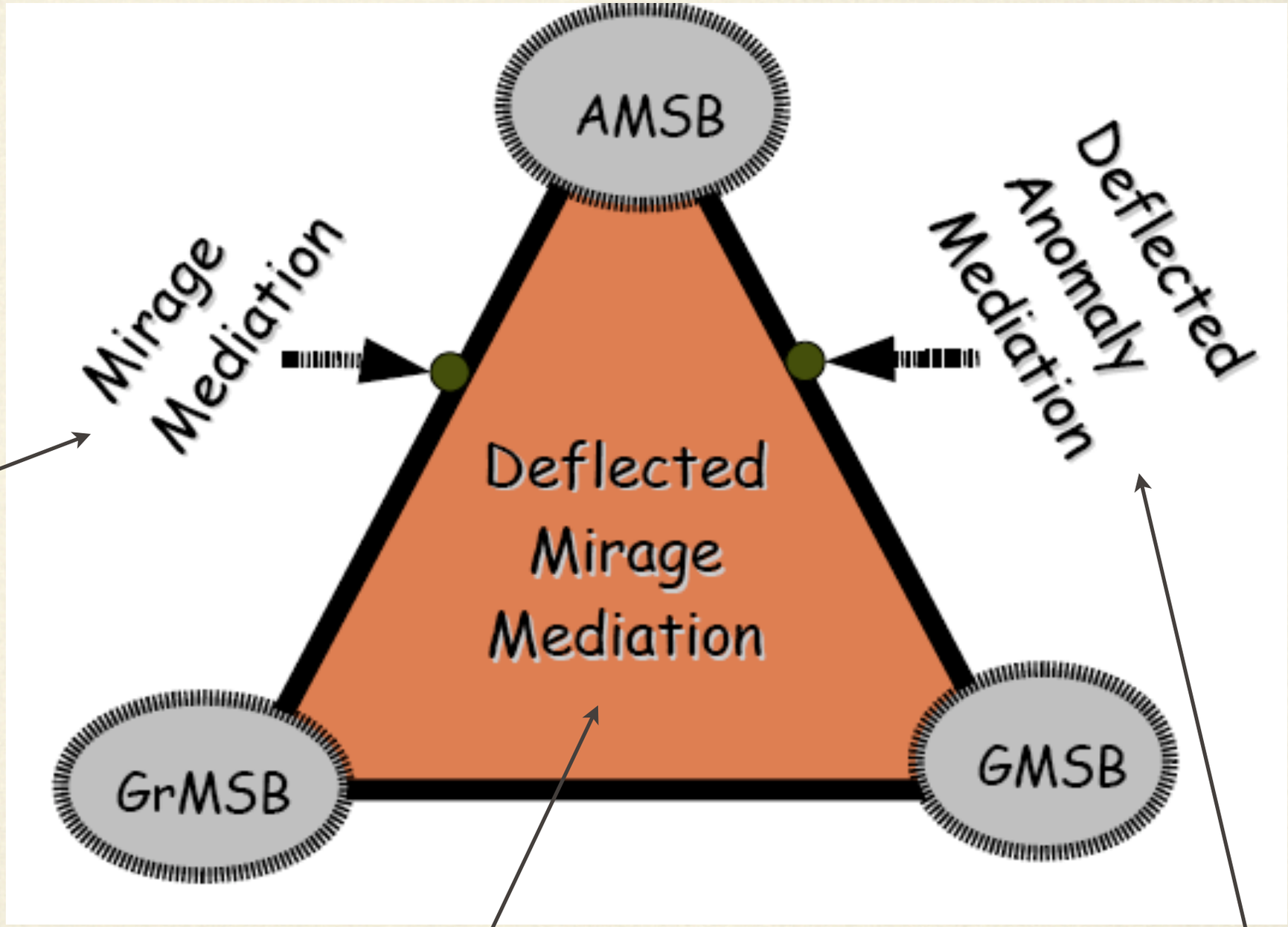


$$M_1 : M_2 : M_3 \simeq 3.3 : 1 : 9$$

One loop level

Motivation for contribution from all types

Use moduli stabilization tricks to make on the same size (KKLT)
K. Choi et al.



This work

Rattazzi and Wells

A model where this happens

All three contributions active

$$W = w_0 + Ae^{-aT} + \lambda X \psi \tilde{\psi}$$

KKLT Superpotential
GrMSB and AMSB same size

New piece

Take GMSB SUSY breaking field X to be matter modulus

Stabilize X by anomaly mediated SUSY breaking terms

$$F^X = -e^{K/2} K^{X\bar{X}} D_{\bar{X}} \bar{W}$$
$$= \underbrace{-e^{K/2} K^{X\bar{X}} \partial_{\bar{X}} \bar{W}}_{(A)} \underbrace{-e^{K/2} K^{X\bar{X}} K_{\bar{X}} \bar{W}}_{(B)}$$

$$\frac{F^X}{X} = -m_{3/2} + \mathcal{O}\left(\frac{m_{3/2}}{8\pi^2}, \frac{F^T}{T+\bar{T}}\right)$$

Phenomenologically interesting

Just parametrize and dial it....

- Three pieces
  - GrMSB (modular weights)
  - AMSB
  - GMSB M_{mess}

$$\frac{F^T}{T+\bar{T}} = m_0$$

$$\frac{F^C}{C} = \alpha_m \ln(m_P/m_{3/2}) m_0$$

$$\frac{F^X}{X} = \alpha_g \frac{F^C}{C}$$

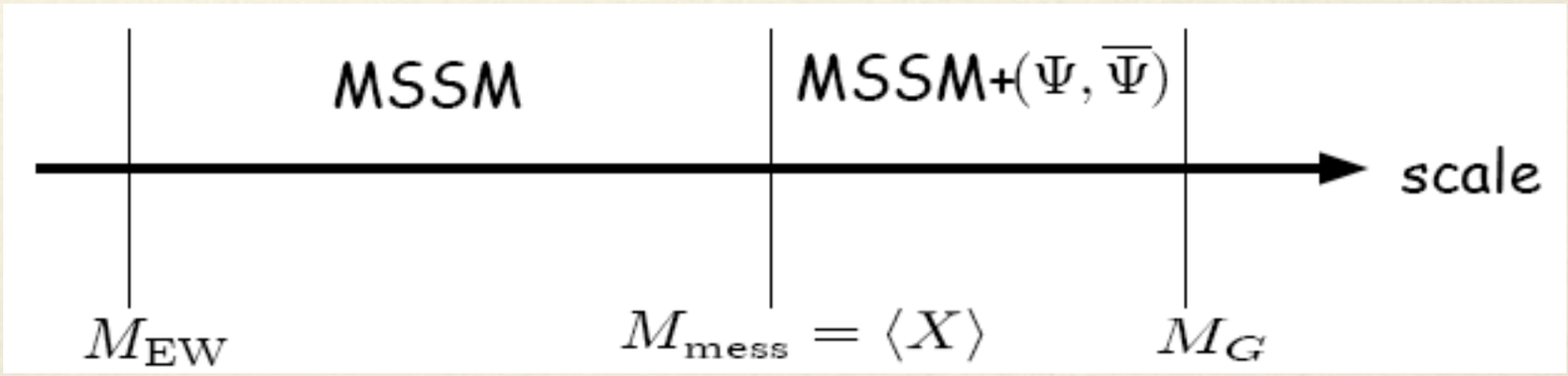
General prescription to include effects of all types of SUSY breaking

And dial the soft masses...

$$
\begin{aligned}
M_a &= F^n \partial_n \log Re(\alpha_a^{-1}(\mu)) \\
A_i &= F^n \partial_n \log e^{-K_0/3} Z_i \\
m_i^2 &= -F^m F^{\bar{n}} \partial_m \partial_{\bar{n}} \log e^{-K_0/3} Z_i
\end{aligned}
$$

$$
Z_i(\mu) = Z_i(\Lambda_{UV}) \prod_a \left(\frac{\alpha_a(\Lambda_{UV})}{\alpha_a(X)} \right)^{\frac{2c_a}{b_a - N}} \left(\frac{\alpha_a(X)}{\alpha_a(\mu)} \right)^{\frac{2c_a}{b_a}}
$$

- Compute UV soft masses
- Run to messenger scale; add in GMSB contribution
- Run to IR



Example: gaugino masses

$$M_a(\mu = M_{\rm GUT}) = \frac{F^T}{T+\bar{T}} + \frac{\alpha_{\rm GUT}}{4\pi} b'_a \frac{F^C}{C}$$

GUT scale

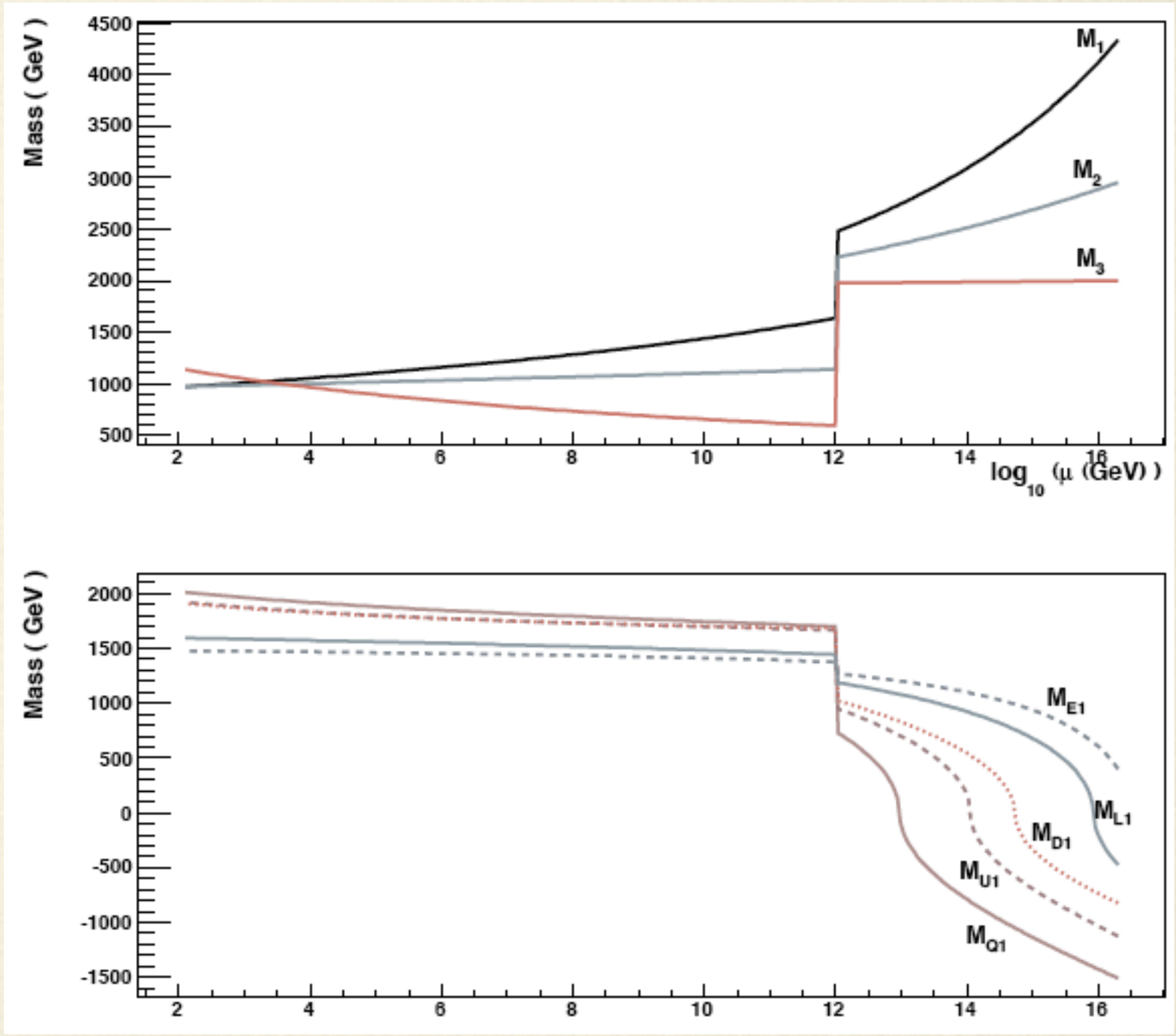
$$M_a(\mu = M_{\rm mess} - \epsilon) = M_a(\mu = M_{\rm mess} + \epsilon) + \Delta M_a,$$

Messenger scale addition

$$\Delta M_a = -\frac{\alpha_a(M_{\rm mess})}{4\pi} N_{mess} \left(\frac{F^C}{C} + \frac{F^X}{M_{\rm mess}} \right)$$

Non-standard points

- Large negative contribution to gaugino masses
- Quasi-conformal running of scalar masses
- Light gluino

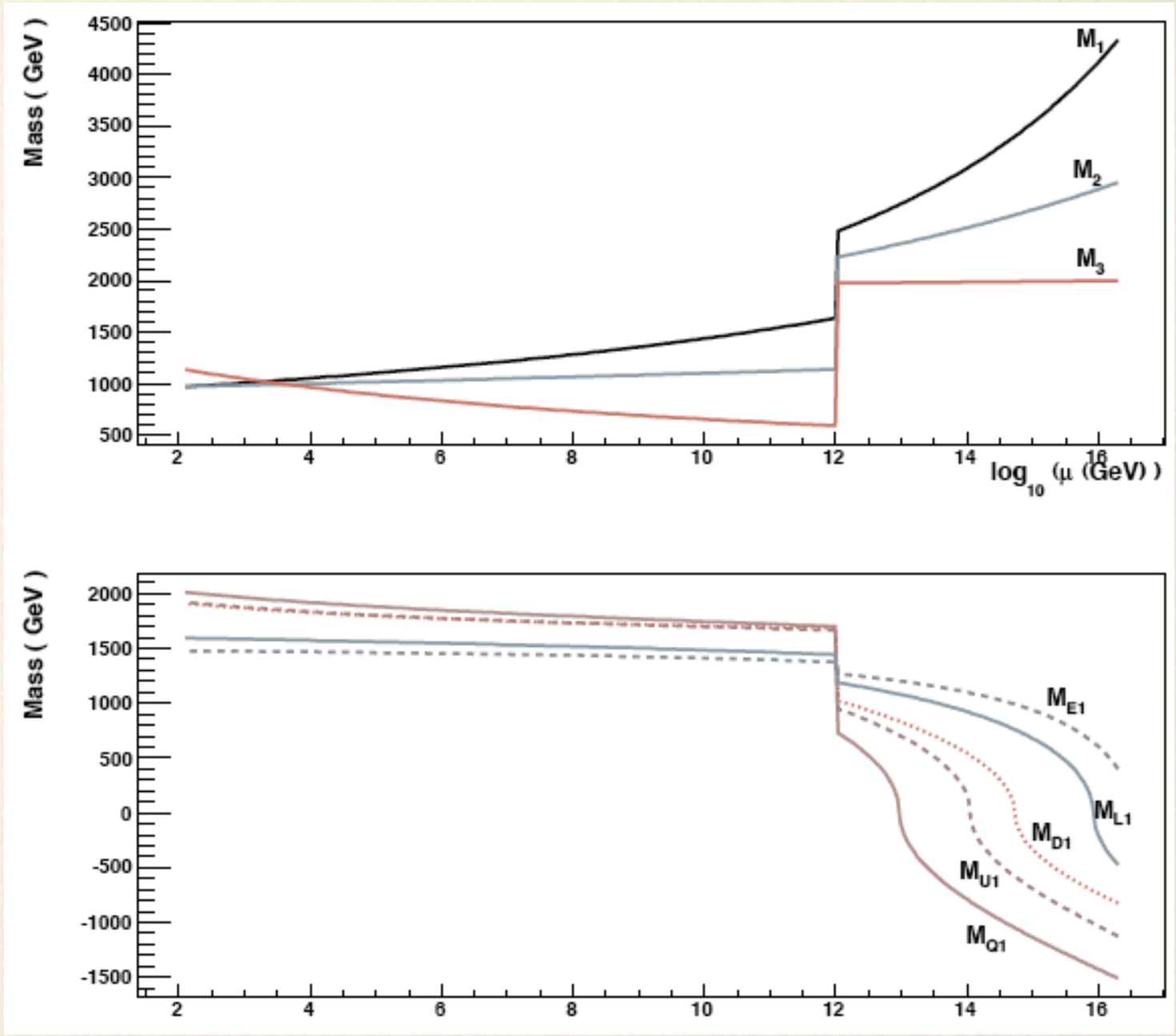


$$\alpha_m = \alpha_g = 1 \qquad M_{mess} = 10^{12}\ \text{GeV}$$

Non-standard points

- Light stop

Point A			
h	117	H, A	1529
$\tilde{g}$	1170	$H^{\pm}$	1531
χ_1^0	1003	χ_2^0	1015
χ_3^0	1374	χ_4^0	1380
$\chi_1^{\pm}$	1011	$\chi_2^{\pm}$	1369
$\tilde{u}_L$	1965	$\tilde{u}_R$	1890
$\tilde{d}_L$	1974	$\tilde{d}_R$	1888
$\tilde{e}_L$	1587	$\tilde{e}_R$	1470
$\tilde{\mu}_L$	1587	$\tilde{\mu}_R$	1470
$\tilde{t}_1$	1420	$\tilde{t}_2$	1791
$\tilde{b}_1$	1769	$\tilde{b}_2$	1872
$\tilde{\tau}_1$	1459	$\tilde{\tau}_2$	1583

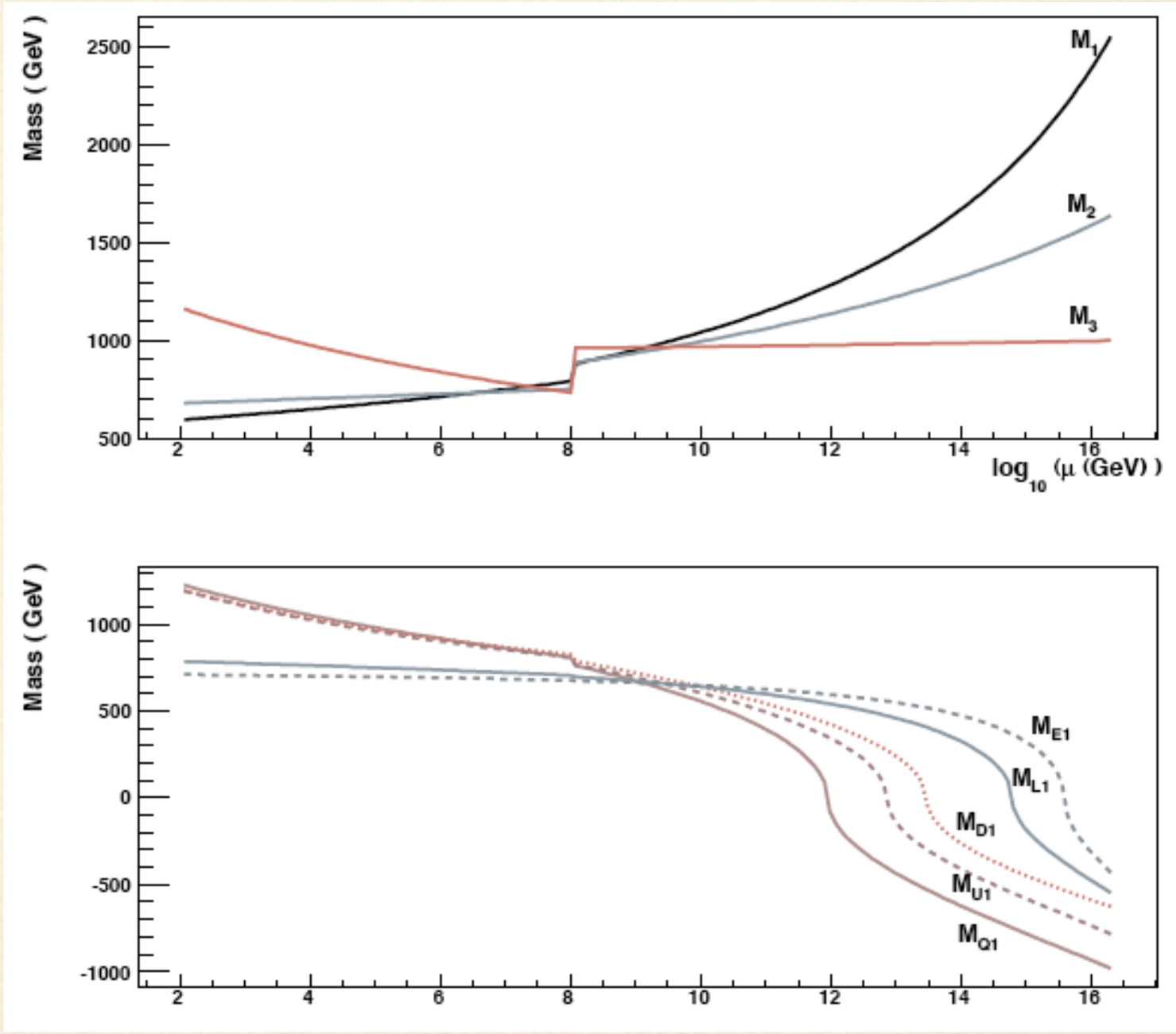


$$\alpha_m = \alpha_g = 1 \qquad M_{mess} = 10^{12}\ \text{GeV}$$

A point of interest

- Compressed spectrum

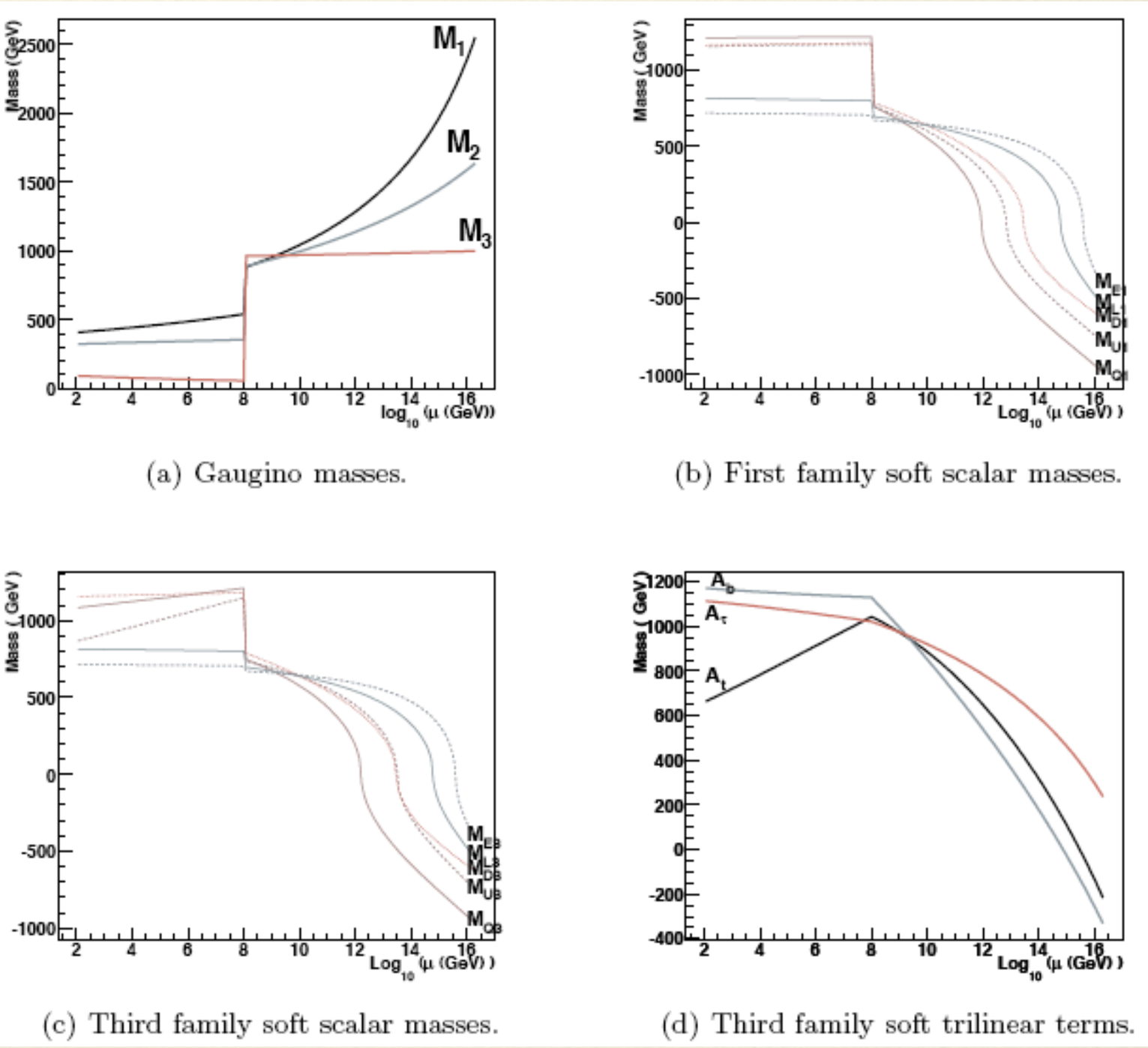
Point B			
h	116	H, A	865
$\tilde{g}$	1130	$H^{\pm}$	869
χ_1^0	608	χ_2^0	683
χ_3^0	818	χ_4^0	844
$\chi_1^{\pm}$	682	$\chi_2^{\pm}$	835
$\tilde{u}_L$	1164	$\tilde{u}_R$	1140
$\tilde{d}_L$	1172	$\tilde{d}_R$	1148
$\tilde{e}_L$	783	$\tilde{e}_R$	709
$\tilde{\mu}_L$	783	$\tilde{\mu}_R$	709
$\tilde{t}_1$	860	$\tilde{t}_2$	1113
$\tilde{b}_1$	1059	$\tilde{b}_2$	1141
$\tilde{\tau}_1$	702	$\tilde{\tau}_2$	782



$$\alpha_m = 1 \quad \alpha_g = 1/2 \quad M_{mess} = 10^8 \text{ GeV}$$

Points of interest

- Very light gluino



(a) Gaugino masses.

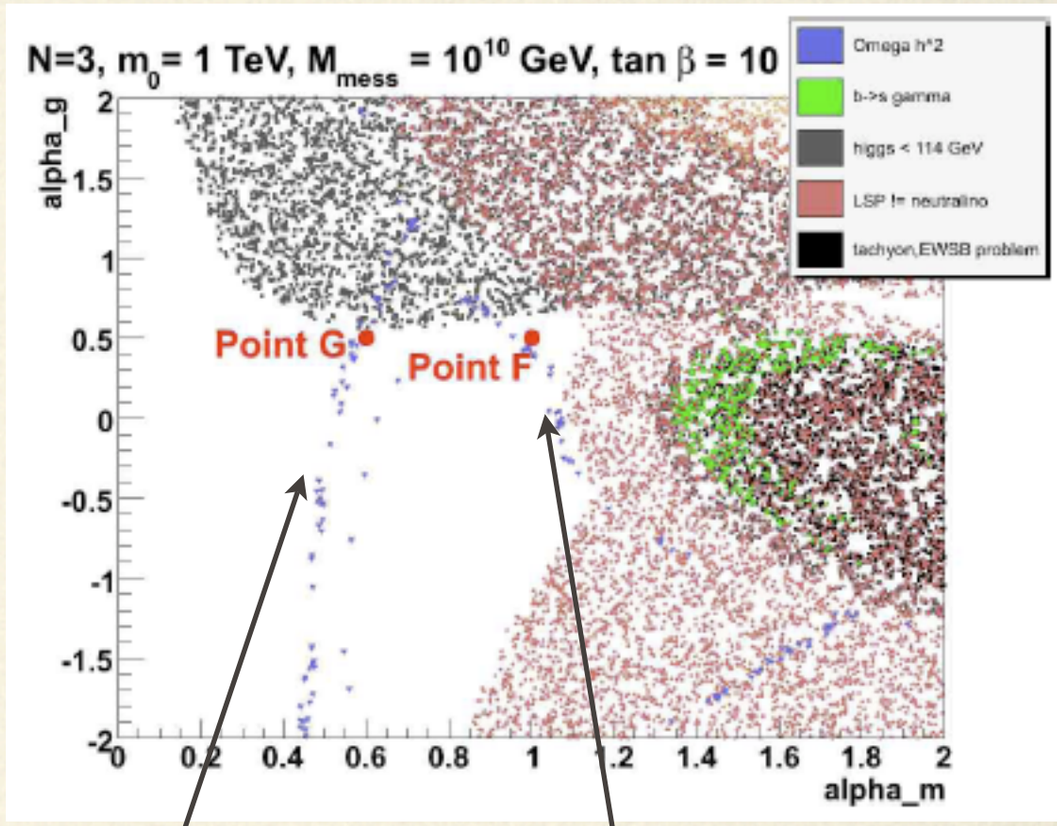
(b) First family soft scalar masses.

(c) Third family soft scalar masses.

(d) Third family soft trilinear terms.

A word on DM phenomenology

- Low scale unification lends itself well to "well-tempered neutralino"
- May have stop co-annihilation
- May naturally have Bino-Wino coannihilation



Funnel BWCA

Conclusions

- A look past mSUGRA
  - Simple framework for generalized SUSY breaking

$$m_0,\ \alpha_g,\ \alpha_m,\ \tan\beta,\ \mathrm{sgn}(\mu)$$

(+ modular weights)

    - Framework can provide for some of the features that have been explored in bottom-up context, such as light gluinos and stops
  - Some mSUGRA folklore shown to be wrong
  - A framework for exploring SUSY more broadly?